Fishery Data Series No. 13-33

Kanalku Lake Subsistence Sockeye Salmon Project: 2012 Annual Report

by

Raymond F. Vinzant

Julie Bednarski

and

Steven C. Heinl

July 2013

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 13-33

KANALKU LAKE SUBSISTENCE SOCKEYE SALMON PROJECT: 2012 ANNUAL REPORT

By

Raymond F. Vinzant and Julie Bednarski

Alaska Department of Fish and Game, Division of Commercial Fisheries, Douglas

and

Steven C. Heinl

Alaska Department of Fish and Game, Division of Commercial Fisheries, Ketchikan

Alaska Department of Fish and Game

Division of Sport Fish, Research and Technical Services

333 Raspberry Road, Anchorage, Alaska, 99518-1565

July 2013

The Kanalku Subsistence Sockeye Salmon Project (Study Number FIS 07-607) was approved by the Federal Subsistence Board, managed by U.S. Fish and Wildlife Service Office of Subsistence Management, funded by the U.S. Forest Service, and is a cooperative project between the U.S. Forest Service, the Alaska Department of Fish and Game, and the Angoon Community Association. This annual report completes contract obligations for Sikes Act Contract numbers AG-0109-C-07-0016. Additional funds for this project were provided by the Alaska Sustainable Salmon Fund.

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

Raymond F. Vinzant and Julie Bednarski,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
802 Third Street, Douglas, Alaska 99824, USA

and

Steven C. Heinl,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
2030 Sea Level Drive, Suite 205, Ketchikan, Alaska 99901, USA

This document should be cited as:
Vinzant, R. F., J. Bednarski, and S. C. Heinl. 2013. Kanalku Lake subsistence sockeye salmon project: 2012 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 13-33, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The sockeye salmon (*Oncorhynchus nerka*) run at Kanalku Lake, Southeast Alaska, has provided the preferred traditional subsistence sockeye salmon stock for the people of Angoon for generations. A stock assessment program at Kanalku Lake began in 2001 in response to community concerns over declining run size and possible overexploitation by local fishermen. Annual escapements were estimated through mark-recapture studies from 2001 to 2006 and through a standard picket weir operated at the outlet of the lake since 2007. In 2012, the best estimate of *spawning* escapement was the picket weir count of 1,123 sockeye salmon, which was validated with a weir-to-spawning grounds mark-recapture estimate of 1,215 sockeye salmon (95% CI 1,000–1,400). In 2012, we operated a pair of video camera-weirs in lower Kanalku Creek to estimate *total* sockeye salmon escapement into the Kanalku system and estimate mortality at Kanalku Falls, a partial barrier to sockeye salmon migration. The estimate of *total* sockeye salmon escapement was 2,289 fish; thus, only 49% of the sockeye salmon that entered Kanalku Creek successfully ascended Kanalku Falls in 2012. Similar to previous years, the escapement was dominated by age-1.2 sockeye salmon (88%). The very low number of 5-year-old sockeye salmon (124 fish) was likely the product of a poor 2007 parent-year escapement of only 461 fish.

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Kanalku Lake, escapement, weir, mark-recapture, age composition, Southeast Alaska, video camera

INTRODUCTION

The coastal village of Angoon, Alaska, located on the western side of Admiralty Island, has a long history of utilizing sockeye salmon (*Oncorhynchus nerka*) from the Kanalku Lake drainage. The use of Kanalku Bay as a traditional subsistence fishery has been documented in several historical and archaeological records, and artifacts from a traditional salmon weir at the head of Kanalku Bay provide physical evidence of the exploitation of salmon resources for at least the last 1,000 years (de Laguna 1960; Moss 1989; Thornton et al. 1990; Goldschmidt and Haas 1998). Although other sockeye salmon runs in the vicinity are available for Angoon subsistence fishermen, including Sitkoh and Basket bays (Geiger et al. 2007), Kanalku Bay remains the preferred harvest area due to its close proximity to the village and ease of access through sheltered waterways.

The introduction of the commercial fishing industry in Southeast Alaska greatly influenced the lives of Alaska Native families since the early 20th century. New federal fishing laws and Alaska Native participation in the commercial fishing industry led to changes in traditional fishing practices among the Natives of Angoon and other Southeast villages (Thornton et al. 1990; Betts and Wolfe 1992; Turek et al. 2006). After the adoption of Alaska statehood, a non-commercial subsistence fishery was defined and put under a permit system (Turek et al. 2006). Residents of Angoon can obtain subsistence fishing permits for Kanalku, Sitkoh, and Basket bays, along with other nearby areas, but most people prefer to fish in Kanalku Bay (Conitz and Burril 2008). Participation in commercial fisheries by Angoon residents has declined since the 1980s. In 1980, 90 Angoon residents fished 134 commercial fisheries permits, by 1990, 76 Angoon residents fished 119 permits, by 2000, 37 Angoon residents fished 46 commercial permits and by 2010, only six Angoon residents fished six commercial permits (data from the Commercial Fisheries Entry Commission, http://www.cfec.state.ak.us/fishery_statistics/earnings.htm). This decline in participation in commercial fisheries has led to a loss in mobility, which has concentrated the Angoon community's subsistence activities closer to home (Bednarski et. al. 2013).

In the late 1990s, annual reported subsistence harvests at Kanalku Bay increased substantially at the same time abundance of Kanalku Lake sockeye salmon appeared to decline. Although reported subsistence harvest tends to under-represent the true community harvest (Conitz and

Cartwright 2003; Lewis and Cartwright 2004; Lorrigan et al. 2004; Walker 2009), the reported harvests are useful for looking at trends in subsistence catch (Geiger et al. 2007). The reported subsistence harvest at Kanalku Bay increased from an average of 580 sockeye salmon in the late 1980s to an average of 1,550 in the late 1990s (Figure 1). Some Angoon residents reported a decline in the overall abundance of Kanalku sockeye salmon in the 1990s and suggested community members "slow down" in harvesting that stock (Conitz and Cartwright 2005; Conitz and Burril 2008).

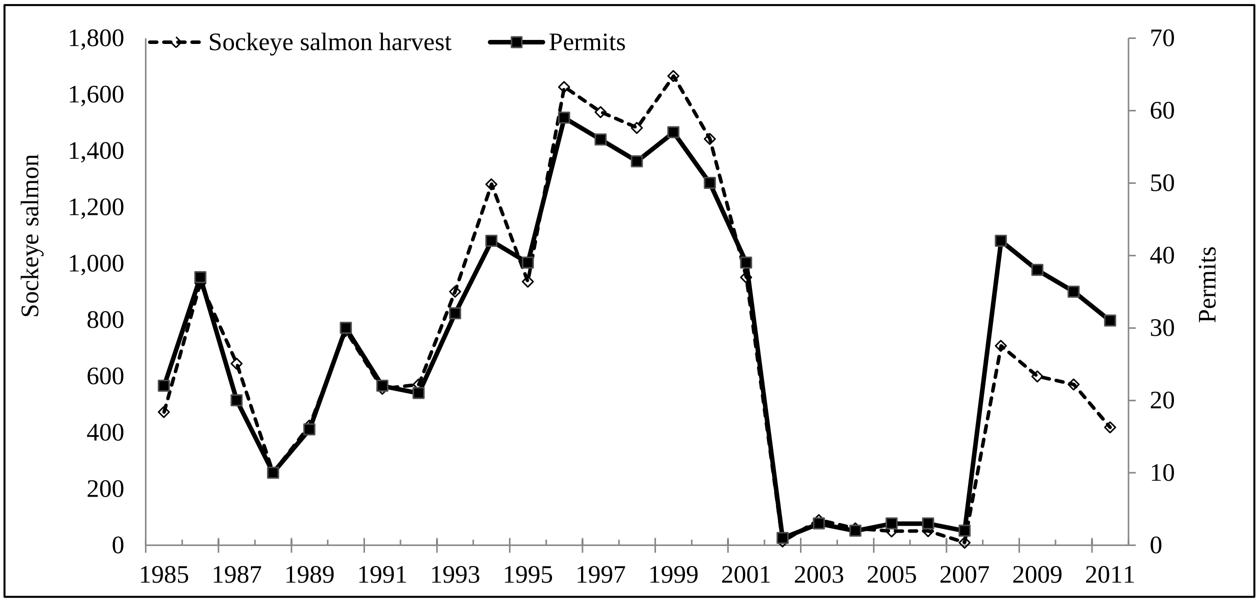

Figure 1.–Reported Subsistence sockeye salmon harvest and permits issued, 1985 to 2011.

The Alaska Department of Fish and Game (ADF&G) initiated a stock assessment program in 2001 in response to the concern about declining run size and the lack of information about spawning escapements (Conitz and Cartwright 2005). From 2001 to 2006, mark-recapture estimates were conducted on the spawning grounds of Kanalku Lake to estimate the spawning population of sockeye salmon. In 2001, the reported subsistence harvest of sockeye salmon at Kanalku Bay far exceeded an alarmingly low mark-recapture estimate of less than 300 sockeye salmon spawners at Kanalku Lake (Conitz and Cartwright 2005; Appendix A). The Angoon community and ADF&G fisheries managers agreed by consensus that the community would voluntarily curtail fishing in Kanalku Bay during at least the first half of the run (defined as through 14 July) for the 2002 season (Conitz and Burril 2008; Bednarski et al. 2013). In addition, harvest limits at other nearby subsistence sockeye salmon fisheries were increased to encourage fishing effort elsewhere and allow the Kanalku stock to rebuild. During the voluntary closure, 2002–2005, the reported harvest of sockeye salmon in Kanalku Bay was minimal. The escapement in 2003 was estimated to be less than 300 sockeye salmon but escapement estimates in 2002 and from 2004 to 2006 averaged about 1,300 fish (Conitz and Cartwright 2005). In 2006, the department and the community agreed to end the voluntary closure at Kanalku. The annual limit was reduced from 25 to 15 fish per household and the fishing season was shifted from 1 June–31 July to 20 July–15 August to allow a conservative harvest and continue to rebuild the run. In 2007, the fishing season was shifted back to 1 June–31 July.

Beginning in 2007, ADF&G, in cooperation with the Angoon Community Association, improved the stock assessment project by installing a fixed picket weir directly below the outlet of Kanalku Lake to observe sockeye salmon run timing, escapement, and conduct a weir-to-spawning grounds mark-recapture estimate of escapement. Escapements were less than 1,000 fish in both 2007 and 2008, but improved to more than 2,500 sockeye salmon in both 2009 and 2010 (Vinzant et al. 2009; Vinzant et al. 2010; Vinzant and Bednarski 2010). The weir count in 2011 was about 700 sockeye salmon (Vinzant et al. 2012), likely a result of the very small brood stock observed in 2007 (Conitz and Burril 2006).

Kanalku Falls, a partial barrier to sockeye salmon migration in Kanalku Creek, is known to have a major influence on the number of the sockeye salmon that successfully make it into Kanalku Lake to spawn. In most years, substantial numbers of sockeye salmon sit in the pools below the falls where they are susceptible to predation and repeatedly batter themselves on the rocks as they attempt to jump the falls and migrate upstream. In 1970, the U.S. Forest Service blasted resting pools and a small channel in the bedrock at the falls to assist migrating salmon (Geiger et al. 2007) but many fish still do not successfully ascend the falls. Our work at the weir, combined with efforts by the U.S. Forest Service, suggests a larger portion of the sockeye salmon run is able to ascend the falls during periods of low water flow (Vinzant et al. 2010; Vinzant and Bednarski 2010). In 2008, a year of high precipitation, we estimated that fewer than half of the sockeye salmon that entered Kanalku Creek successfully ascended Kanalku Falls, whereas in 2009, a year of low precipitation, about 75% of the sockeye salmon were able to pass the falls (Vinzant et al. 2010).

Sockeye salmon escapement into Kanalku Lake may also be affected by interception in nearby commercial fisheries conducted in Chatham Strait where sockeye salmon are harvested incidentally in purse seine fisheries targeting pink salmon (*O. gorbuscha*). Although we have no estimates of the harvest of Kanalku sockeye salmon, management of the Chatham Strait fisheries is based on the assumption that this interception is insignificant because of the early run timing of Kanalku sockeye salmon compared to the timing of fishery openings, the distance of Kanalku Bay from these fisheries, and the nature of the mixed stock area where fishing occurs (Geiger et al. 2007). Based on subsistence harvest data collected since 1985, 87% of the total season’s subsistence harvest is completed by the time the first purse seine fishery opens in Upper Chatham Strait, and 97% by the end of July (Geiger et al. 2007). In addition, the Chatham Strait shoreline along an area of approximately nine nautical miles from Parker Point to Point Samuel, west and north of Kootznahoo Inlet and the community of Angoon and Kanalku Inlet, has been closed to the purse seine fishery.

The primary focus of the sockeye salmon assessment project has been to produce reliable annual estimates of the spawning escapement into Kanalku Lake. This was the 6th year of weir operations at the outlet stream of Kanalku Lake. Our crew counted fish entering the lake, observed run-timing, collected biological data, and estimated the spawning escapement of sockeye salmon with a weir-to-spawning grounds mark-recapture estimate. In 2012 we expanded our project objectives to better understand the sockeye salmon mortality associated with passage over Kanalku Falls. We incorporated two camera-weirs located on lower Kanalku Creek, below Kanalku Falls, to estimate the *total* sockeye salmon escapement into the system. To provide a precise estimate of mortality at Kanalku Falls, we compared the *total* escapement counted in the lower creek to the *spawning* escapement counted at the standard picket weir at the outflow of Kanalku Lake.

OBJECTIVES

1. Count all salmon species entering lower Kanalku Creek, below Kanalku Falls, through a series of two double-camera weirs for the duration of the sockeye salmon run to estimate *total* escapement.
2. Count all salmon species passed through a picket weir into Kanalku Lake for the duration of the sockeye salmon run to estimate *spawning* escapement.
3. Validate the picket weir escapement count with a mark-recapture estimate of the sockeye salmon spawning population with an estimated coefficient of variation no greater than 15% of the point estimate.
4. Estimate the sockeye salmon mortality rate at Kanalku Falls.
5. Estimate the age, length, and sex composition of the Kanalku Lake sockeye salmon *spawning* escapement such that the estimated proportion of each age class is within 5% of the true value with at least 95% probability.

METHODS

STUDY SITE

Kanalku Lake (lat. 57^{o} 29.22'N, long. 134^{o} 21.02'W) is located about 20 km southeast of Angoon (Figure 2) and lies in a steep mountainous valley within the Hood-Gambier Bay carbonates ecological subsection (Nowacki et al. 2001). The U-shaped valley and rounded mountainsides are characterized by underlying carbonate bedrock and built up soil layers supporting a highly productive spruce forest, especially over major colluvial and alluvial fans (Nowacki et al. 2001). The watershed area is approximately 32 km^2, with one major inlet stream (ADF&G stream no. 112-67-060) draining into the east end of the lake. The lake elevation is approximately 28 m. The lake surface area is approximately 113 hectares, with mean depth of 15 m, and maximum depth of 22 m (Figure 3). The outlet stream, Kanalku Creek (ADF&G stream no. 112-67-058), is 1.7 km long and drains into the east end of Kanalku Bay. In addition to sockeye salmon spawning in the lake, large numbers of pink salmon spawn in the lower part of the outlet creek and intertidal area. A few coho (*O. kisutch*) and chum (*O. keta*) salmon spawn in the Kanalku system, and resident populations of cutthroat trout (*O. clarkii*), Dolly Varden char (*Salvelinus malma*), and sculpin (*Cottus sp.*) are found in Kanalku Lake. Kanalku Falls, a waterfall approximately 8–10 m high and about 0.8 km upstream from the tidewater, forms a partial barrier to migrating sockeye salmon.

SOCKEYE SALMON TOTAL ESCAPEMENT ESTIMATE

The *total* sockeye salmon escapement of the Kanalku Lake system was counted through a series of two video camera-weirs located approximately 0.5 km upstream from the mouth of Kanalku Creek, and 0.4 km downstream of Kanalku Falls. Two video cameras on each camera-weir were used to count fish that freely passed the camera-weirs 24 hours per day. The two-weir system was used to validate the camera-weir counts and eliminated the need for a back-up mark-recapture estimate.

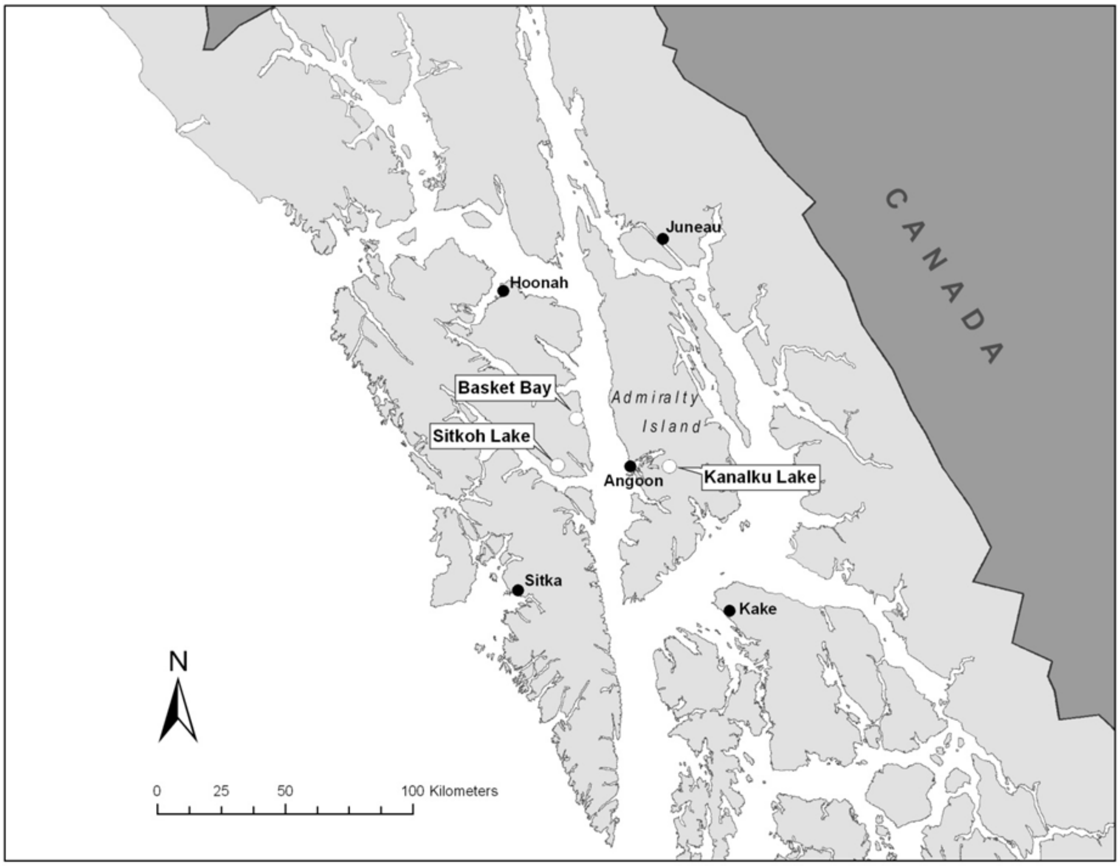

Figure 2.–Map of Southeast Alaska showing location of Kanalku Lake and the village of Angoon.

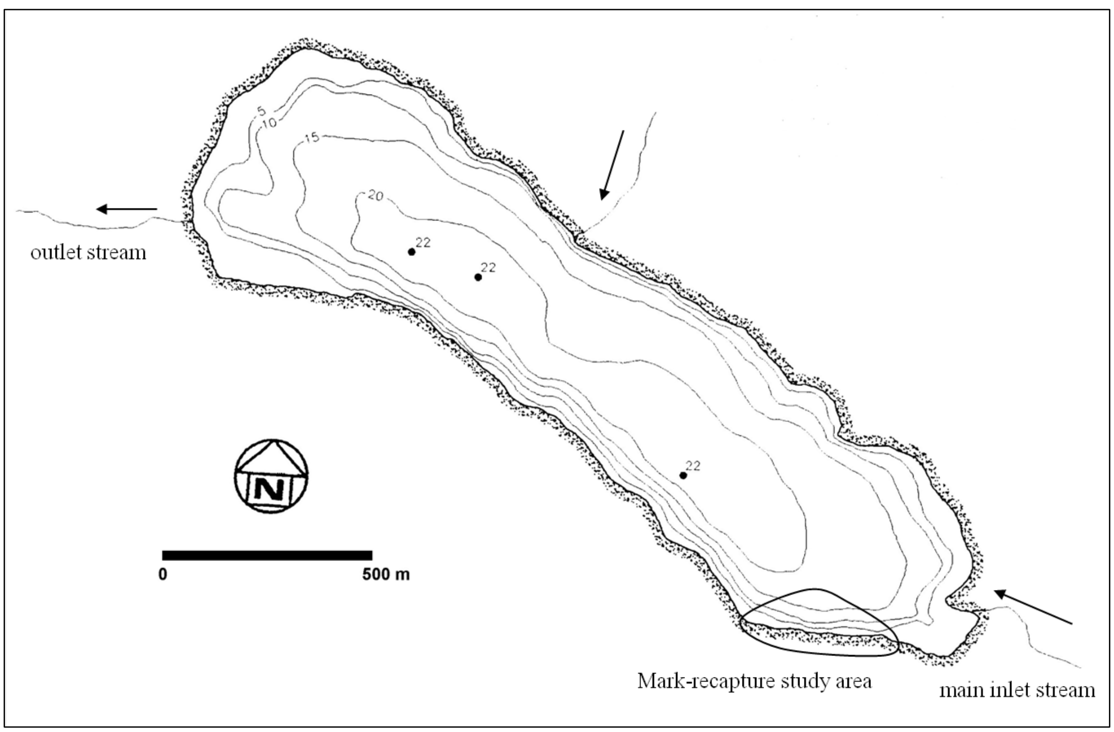

Figure 3.–Bathymetric map of Kanalku Lake showing 5-m depth contours and the mark-recapture study area. Arrows indicate direction of stream flow.

Lower Creek Camera-Weirs

The camera-weirs were operated from 13 June to 28 August. The camera-weirs were constructed by anchoring an aluminum video chute (Figure 4) to the stream bed. A series of weir panels were attached to each side of the video chute and anchored into the stream bed and aligned in a "V" shape to help guide fish quickly through the chute (Figure 5). The weir panels were fitted with 1.5-m tall, 1.3-cm diameter EMT conduit pickets with "pink salmon" spacing of 4.45 cm on center. Vinyl-coated welded wire fencing (2.5 cm^2 mesh) was attached to the weir panel ends and extended to the stream banks as wings. The fencing material was supported by a series of 2-m fence posts driven into the stream bottom spaced approximately 2.4 m apart. Two rows of 1.3 cm EMT conduit were used as horizontal stringers and attached to the vertical posts. The fencing material was also folded to form an apron on the upstream side of the weir, approximately 45 cm wide, and was secured to the stream bottom with a double row of sandbags. The fencing material was secured to the EMT stringers and posts with cable ties. The crew cleaned the weirs daily, checked for holes or scouring, and ensured the structure was fish-tight.

Camera Counts

Two underwater color video cameras containing Sony 8.47 mm HAD CCD 3.6 mm sensors were installed on the left and right sides of the video chute to observe passing fish. Video cables transferred the data from the camera to mini-DVRs (Digital Video Recorders). The video was motion-detected, 30-frames-per-second, and video files were stored on SD memory cards. The video chute was lighted at night by two bright white 25.4 cm, 14-bulb bright white LED light strips attached to the top of the video camera chutes. Photoelectric sensors were used to turn the lights on only from dusk to dawn to conserve battery power. The paired video systems at each video chute were powered by two 140-watt solar panels that trickle charged a 100 ah AGM (absorption glass matt) 12V DC battery through a metered 30A charge controller. The solar panels were positioned to face both the morning and afternoon sun. The mini-DVRs and a 17.78 cm color TFT monitor were housed in a Pelican case (Figure 6). DC voltage converters were used to regulate power to the mini-DVRs (5V DC).

At each camera station, a pair of SD cards (for left and right cameras) were changed out daily. The crew used a laptop computer to review video data back at camp. All video footage was reviewed daily by the crew, and separate counts were kept for all salmon species captured by the cameras at each of the camera-weirs. Counts by hour for each camera and any other observations were recorded onto spreadsheets. Video files were backed up on a laptop computer and an external hard drive daily. At the end of the season, video files were reviewed again to corroborate inseason counts.

SOCKEYE SALMON SPAWNING ESCAPEMENT ESTIMATE

The standard picket weir was again used in 2012 to estimate the *spawning* escapement of sockeye salmon into Kanalku Lake, and validated with a mark-recapture estimate conducted on the spawning grounds. The spawning escapement was directly compared to the *total* escapement (from the camera-weirs) to estimate the natural mortality incurred at Kanalku Falls.

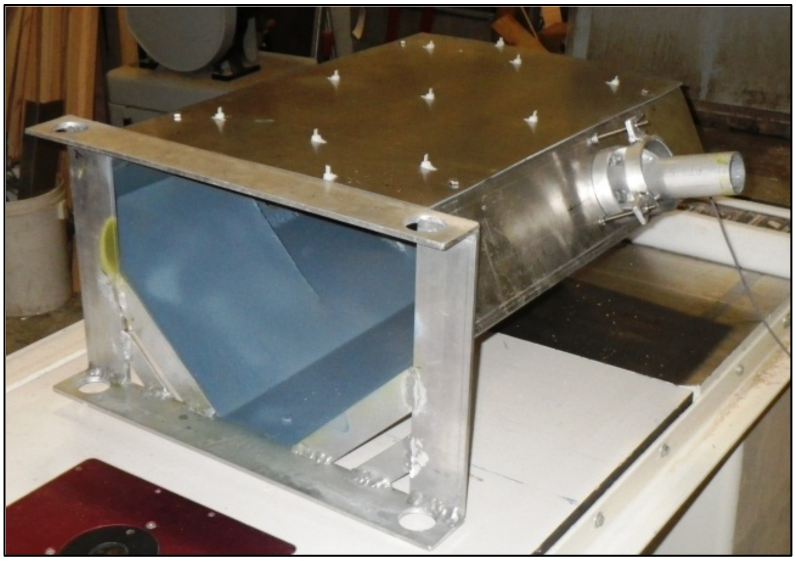

Figure 4.–Aluminum video chute used on camera-weirs. Adjustable camera mount shown on right side of chute. (©2012 ADF&G/photo by Raymond F. Vinzant.)

Figure 5.–Camera-weirs installed in lower Kanalku Creek, below Kanalku Falls, 2012. (©2012 ADF&G/photo by Raymond F. Vinzant.)

Figure 6.–Camera-weir video recording components housed in waterproof Pelican case. (©2012 ADF&G/photo by Raymond F. Vinzant.)

Picket Weir Count

The Kanalku weir was located in Kanalku Creek, across the outlet stream at the west side of the lake. The weir consisted of aluminum bipod supports anchored in the stream sediment. The supports were connected by rows of stringers that extended across the entire stream bed, with pickets inserted through regularly-spaced holes in the stringers and extended to the stream bottom. Picket spacing was 4.45 cm on center of the pickets. This spacing allowed for 52 pickets per channel with a maximum space of approximately 3.81 cm between pickets. Sandbags were placed across the stream along both sides of the weir to help stabilize the substrate and secure the pickets in place. A weir trap, sampling station, and catwalk were constructed and attached to the weir. Technicians inspected the weir daily for malfunction and breaches.

To minimize handling, fish were counted through the weir by pulling one or two pickets at the upstream side of the weir trap. White sandbags were placed on the bottom of the stream bed at the exit point to aid in fish identification. In addition to counting all fish by species, all sockeye salmon were visually categorized as jacks (fish less than 400 mm in length) or full-size adults. Daily observations of the water level (cm), air and water temperature (°C), and weather were recorded at the weir. The weir was in operation from 25 June to 3 September. Water level was measured daily at approximately the same location (within 1 m^2) as the 2007 to 2011 field seasons.

Weir-to-Spawning Grounds Mark-Recapture Estimate

The *spawning* population of sockeye salmon was estimated with a two-event mark-recapture study for a closed population (Seber 1982). The mark-recapture study allowed us to determine if sockeye salmon passed through the weir undetected, and served as a back-up estimate if the weir was breached or damaged. In Event 1, fish were marked at the weir with a combination of an adipose fin clip and either an axillary process clip or dorsal fin clip. Marking at the weir was stratified through time on the following schedule: left axillary process clip from 2 July to 23 July, right axillary process clip from 24 July to 8 August, and dorsal fin clip from 9 August to 29 September. The adipose fin clip facilitated easy identification of marked fish and served as the primary mark. Any fish marked and released with only an adipose fin clip was noted. To minimize handling, fish sampled for age, sex, and length were also marked. The target marking rate was 35% of the weekly sockeye salmon escapement. Sockeye salmon that appeared unhealthy were enumerated and released without marks.

In Event 2, fish were sampled for mark recovery with a beach seine in the only major spawning area found in Kanalku Lake (Conitz and Burril 2008), which is located along the eastern shoreline adjacent to the mouth of the inlet stream (Figure 3). Sampling occurred on 4 September, 10 September, 14 September, and 20 September 2012. An opercular punch was applied to all sockeye salmon in these samples to prevent double sampling on that day or on subsequent sampling days.

We used Stratified Population Analysis System (SPAS) software (Arnason et al. 1996; http://www.cs.umanitoba.ca/~popan/) to analyze mark-recapture data. SPAS was designed for analysis of two-sample mark-recapture data where Event 1 (marking) and Event 2 (mark-recovery) samples are collected over a number of strata. This software was used to calculate the maximum likelihood Darroch and pooled-Petersen (Chapman's modified) estimates and their standard errors. We evaluated the validity of full pooling of marking and mark-recovery data (pooled-Petersen estimate) by using the first two chi-square tests provided in the output. These tests provided a reasonable indication of serious violation of the basic mark-recapture assumptions by evaluating 1) complete mixing of marked fish between release (Event 1) and recovery (Event 2) strata, and 2) equal proportions of fish recovered from each marking stratum. A test statistic with $P \leq 0.05$ was considered "significant," but bias was indicated in the pooled-Petersen estimate only if both test statistics were significant. If one or neither test statistic was significant, we accepted the pooled-Petersen estimate. Otherwise, we evaluated the stratified Darroch estimate and attempted to find a reasonable partial pooling scheme in order to reduce the number of parameters that needed to be estimated. We used two additional goodness-of-fit tests for the Darroch estimate provided in the SPAS software, along with guidelines and suggestions in Arnason et al. (1996) and Schwarz and Taylor (1998), to evaluate the estimate and partial pooling schemes. We deemed the weir count of sockeye salmon to be "verified" if the count fell within the 95% confidence interval of the mark-recapture estimate.

If we used a pooled-Petersen estimate, a parametric bootstrap procedure was used to estimate the standard error and construct the 95% confidence interval for the escapement estimate. We assumed the number of marked fish recaptured in Event 2 (r) follows a hypergeometric probability distribution. Then we used the number of fish marked in Event 1 (m), the number of fish caught in Event 2 (c), and the Petersen estimate of escapement, $\hat{N}$, to generate 5,000 simulated recapture numbers based on the hypergeometric probability density function, $f(r|\, m, c, \hat{N})$. From the bootstrap values of r, we derived 5,000 Petersen escapement estimates, then calculated the standard error of these estimates and used the 0.025 and 0.975 quantiles to form the 95% confidence interval.

To test the assumption that fish of different sizes were captured with equal probability during sampling Event 1 (marking) and sampling Event 2 (recovery), we compared the length distributions of fish for groups of fish marked at the weir (m), fish captured on the spawning grounds (c), and marked fish recaptured (r) on the spawning grounds using the Kolmogorov-Smirnov (K-S) two-sample test (Conover 1999; Appendix B). The test hypothesis for each comparison was that there were no differences in the length of fish between the data sets being tested ($P > 0.05$). Similarly, we conducted two chi-square consistency tests to check for gender-selective sampling with the test hypothesis that there were no differences in the ratio of males to females between the data sets being tested ($P > 0.05$). Gear selectivity in Event 1 was examined by comparing the number of fish of each gender marked in Event 1 and the number of fish of each gender sampled for marks in Event 2. Sampling bias in Event 2 was examined by comparing the number of fish of each gender marked in Event 1 and recaptured during Event 2 to the number of each gender that were marked but not recaptured.

ESTIMATE OF MORTALITY RATE AT KANALKU FALLS

The mortality rate at the Kanalku Falls (i.e., the number of fish that did not successfully ascend the falls) was estimated by subtracting the best estimate of *spawning* escapement from the estimated *total* sockeye salmon escapement into the Kanalku Creek system.

ADULT POPULATION AGE AND SIZE COMPOSITION

Based on the work by Thompson (1992), and assuming a run of around 1,000 sockeye salmon, a sample of 338 fish was determined to be the size needed to ensure the estimated proportions of each age class would be within 5% of the true value 95% of the time. We increased our sampling goal to 425 fish to ensure we met the target sample size even if 25% of the scale samples were unreadable. We began the season with a weekly sampling goal of 30% of the cumulative weekly escapement. Weekly sampling goals were adjusted by the project leader depending on inseason run strength. All sockeye salmon to be marked for the mark-recapture study were sampled to minimize fish handling; however, if a fish appeared overly stressed after marking, or if the handling time exceeded 30 seconds out of the water, the fish was released without additional sampling. The length of each fish was measured from mideye to tail fork, to the nearest millimeter (mm). Sex was determined by length and shape of the kype or jaw. Three scales were taken from the preferred area of each fish (INPFC 1963), mounted on a gum-card, and prepared for analysis as described by Clutter and Whitesel (1956).

Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g., 1.3 denotes a five-year-old fish with one freshwater and three ocean years; Koo 1962). We estimated multiple age-class proportions and means, together with estimates for their standard errors, as described by Thompson (1992) and Cochran (1977). The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week were calculated using equations from Cochran (1977; Appendix C).

RESULTS

SOCKEYE SALMON TOTAL ESCAPEMENT ESTIMATE

Lower Creek Camera-Weir Count

The dual camera-weirs on lower Kanalku Creek, below Kanalku Falls, were in operation between 13 June and 28 August (Figure 7). The first sockeye salmon of the season was recorded on 24 June (Figure 7; Appendix D). A total of 2,289 adult sockeye salmon were counted through the lower camera-weir and 2,265 adult sockeye salmon were counted through the upper camera-weir (or 1% less than the lower weir). These counts were reviewed and confirmed post season. Both camera-weirs were operated without major incident throughout the season. Neither of the camera-weirs was breached by high water events, and no holes or gaps were found in the weirs that allowed fish to pass undetected. The difference in counts between the camera-weirs was likely due to predation on sockeye salmon between the weirs by river otters (*Lontra canadensis*) and brown bears (*Ursus arctos*) which was observed throughout the season. We chose the larger, lower camera-weir count of 2,289 as the best estimate of the *total* sockeye salmon escapement (Appendix D).

Sockeye salmon migration into lower Kanalku Creek was highest between 16 July and 10 August, and the highest daily count occurred on 28 July when 270 adult sockeye salmon were counted (Figure 7). Sockeye salmon primarily migrated through the weirs in the darkness between the hours of 23:00 and 04:00 (Figure 8). Other species of fish counted included 409 pink salmon, 2 coho salmon, 11 chum salmon, and 2 Chinook (*O. tshawytscha)* salmon (Appendix D). We considered those counts to be incomplete, because pink and chum salmon spawn downstream of the weir site and coho salmon migration occurs primarily after the project ended. Dolly Varden and cutthroat trout were also abundant but not enumerated, because they could also pass freely through the weir and bypass the video-chutes entirely.

SOCKEYE SALMON SPAWNING ESCAPEMENT ESTIMATE

Picket Weir Count

The field crew at Kanalku Lake passed a total of 1,123 adult sockeye salmon through the picket weir between 25 June and 4 September (Figure 9; Appendix E). The first day sockeye salmon were counted at the picket weir was 15 July; 21 days after fish were first observed at the camera-weirs below Kanalku Falls (Figures 7 and 10). No other salmon species or jack sockeye salmon were counted at the weir. No high water events occurred and no holes were found in the weir that would have allowed fish to pass uncounted. Daily sockeye salmon counts were greatest between 22 July and 10 August. Peak daily escapement occurred on 27 July when 108 sockeye salmon were passed through the picket weir.

The result of the chi-square test of complete mixing of marked fish between the marking (Event 1) and recovery (Event 2) events was significant ($\chi^2 = 0.25$, $P < 0.05$, df = 3). However, the result of the test for equal proportions of marked fish on the spawning grounds was not significant ($\chi^2 = 15.43$, $P = 0.97$, df = 3). A non-significant result for one of these diagnostic tests indicated the pooled estimator was appropriate for estimating abundance. Size selectivity was not detected for Event 1; there was no significant size difference between all fish sampled (*c*) during Event 2 and fish marked in Event 1 and recaptured (*r*) in Event 2 (D = 0.04, $P = 0.99$; Appendix B). There was a significant difference in the size of fish marked (*m*) during Event 1 and the size of marked fish recaptured (*r*) during Event 2 (D = 0.31, $P = < 0.01$; Appendix B). These results further suggest abundance can be estimated using a pooled-Petersen model from the entire data set without stratification. We determined that no gender-related gear selectivity occurred during Event 1: the test for equal proportions of males and females marked in Event 1 and sampled in Event 2 was not significant ($\chi^2 = 0.00$, $P = 0.99$, df = 1; Appendix F). There was sampling bias related to gender during Event 2: the test of the frequency of marked males and females recovered compared to those not recovered in Event 2 was significant ($\chi^2 = 7.42$, $P = <0.01$, df = 1).

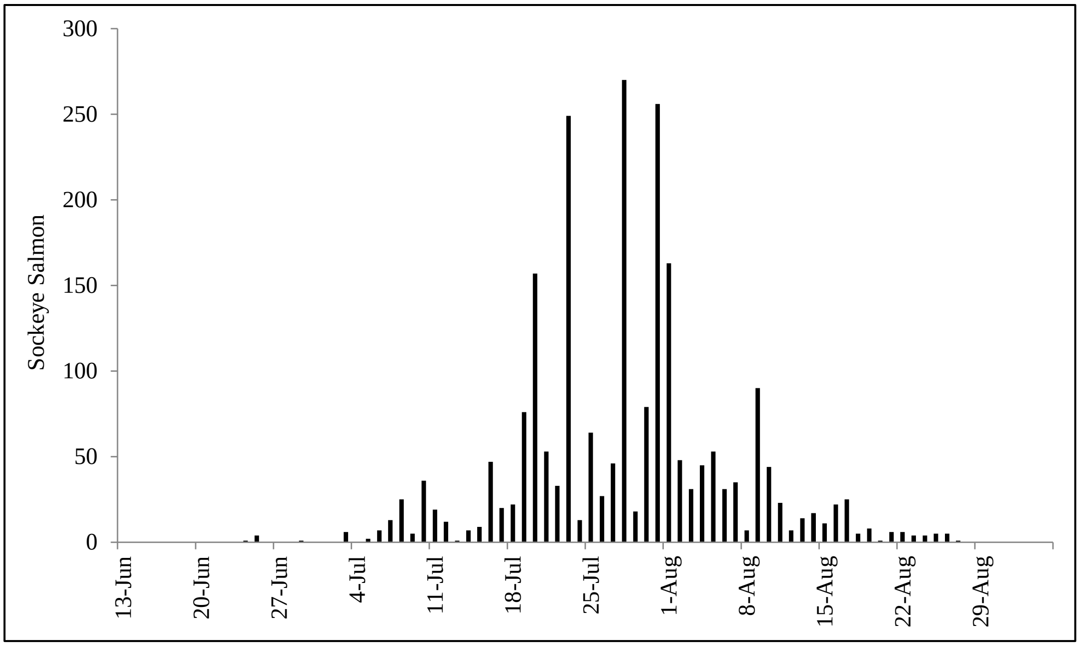

Figure 7.–Daily sockeye salmon escapement counts at the lower Kanalku Creek camera-weir, 2012.

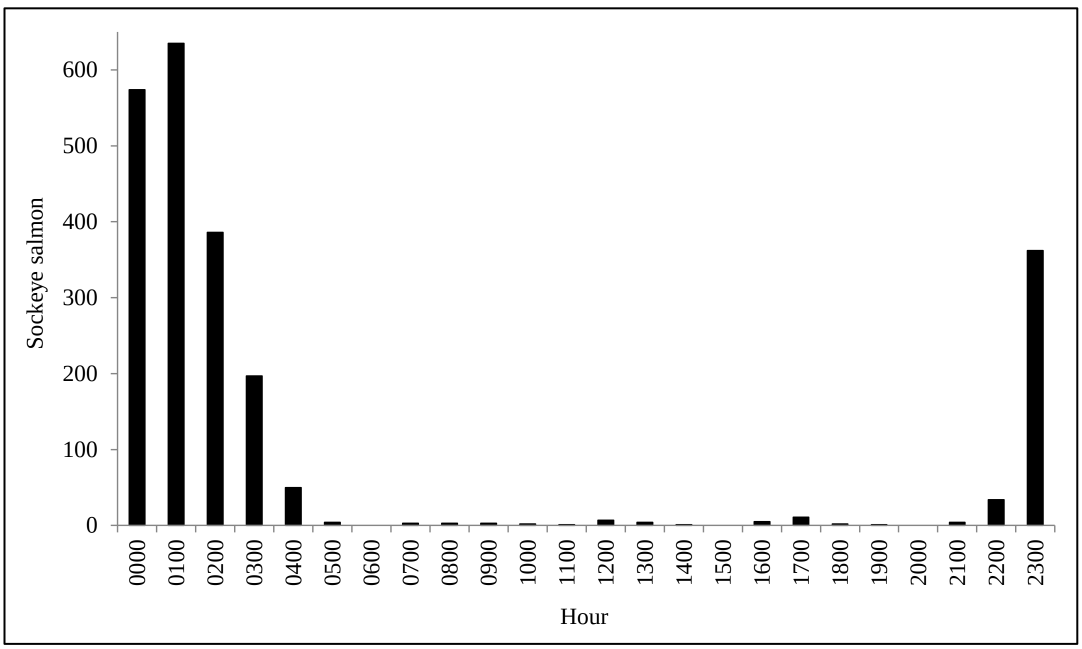

Figure 8.–Cumulative sockeye salmon counts by hour at the lower Kanalku Creek camera-weir, 2012.

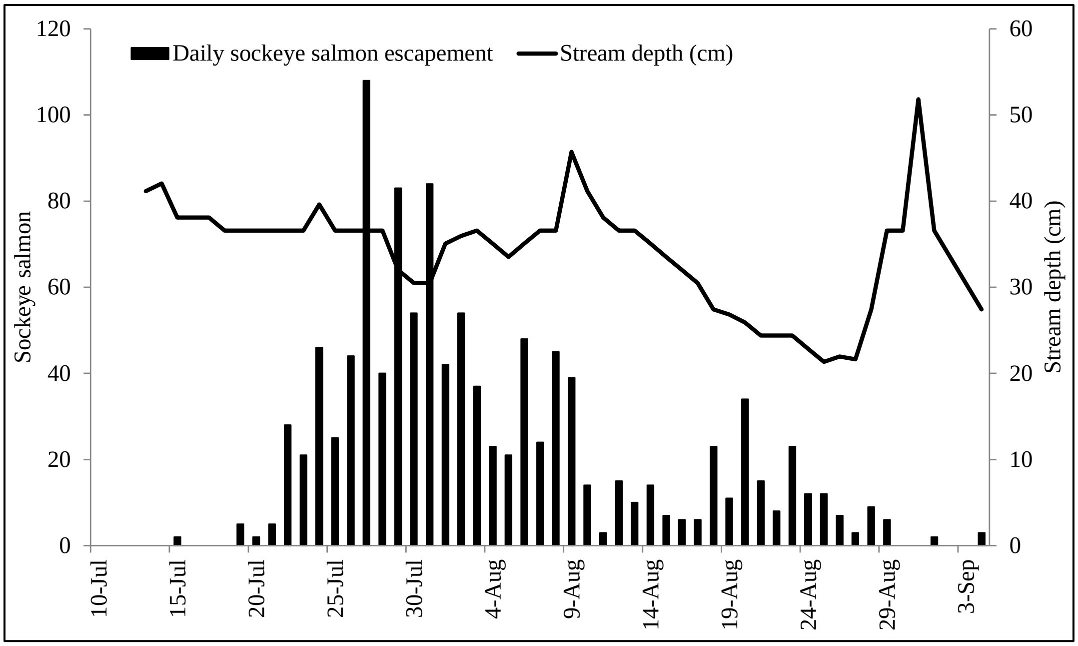

Figure 9.–Picket weir daily sockeye salmon escapement and stream depth (cm), Kanalku Lake, 2012.

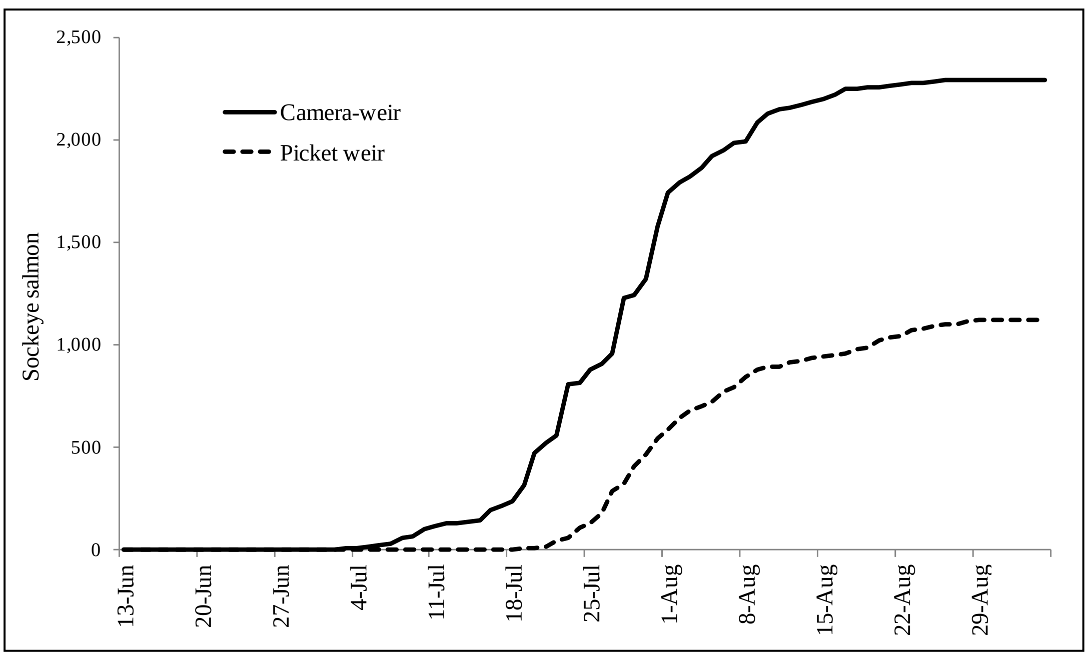

Figure 10.–Comparison of timing and cumulative escapement of sockeye salmon between the camera-weirs on lower Kanalku Creek and the picket weir near Kanalku Lake, 2012.

We pooled the mark-recapture data and calculated a Petersen estimate of 1,215 (SE = 96) adult sockeye salmon, with a 95% confidence interval of approximately 1,000–1,400 fish. The coefficient of variation (CV) of 7.9% met our objective of an estimate with a CV of less than 15%. Since the weir count of 1,128 fit within the 95% confidence interval of the mark-recapture estimate, we used the weir count as our best estimate of the *spawning* escapement in 2012 (Table 1).

Table 1.–Number of sockeye salmon marked at the weir, number sampled for marks, and number recaptured at the Kanalku Lake spawning area in 2012 by marking stratum.

Marking stratum end date	Number marked at weir	Count at weir	Marks recovered by sampling date				Total marks recovered	Proportion of marks recovered
			4-Sep	10-Sep	14-Sep	20-Sep		
24-Jul	26	109	3	0	1	0	4	0.15
9-Aug	304	771	22	31	10	8	71	0.23
4-Sep	117	243	1	4	1	2	8	0.07
Total	447	1,123	26	35	12	10	83	0.19
Total fish sampled			67	100	33	27	227	
Proportion marked in samples			0.39	0.35	0.36	0.37	0.37	

ADULT POPULATION AGE AND SIZE COMPOSITION

The crew at Kanalku Lake sampled 360 adult sockeye salmon for age, sex, and length composition in 2012, of which 318 were successfully aged. Age composition of the sockeye salmon sampled was primarily age-1.2 fish from the 2008 brood year (88%). Other sockeye salmon were age-2.2 (4%) and age-1.3 (7%) from the 2007 brood year. A very small number of age-3.2 fish (1%) from the 2006 brood year were also found (Table 2). Age-1.2 fish had a mean length of 513 mm for males and 501 mm for females, and age-1.3 fish had a mean length of 560 mm for males and 552 mm for females (Table 3).

Table 2.–Estimated age composition of the 2012 sockeye salmon escapement at Kanalku Lake based on scale samples, weighted by statistical week.

Brood year	2008	2007	2007	2006	
Age	1.2	2.2	1.3	3.2	Total
Sample size	282	15	19	2	318
Escapement by age class	994	49	75	6	1,123
SE of escapement	18	11	14	3	
Percent	88%	4%	7%	1%	
SE of %	2%	1%	1%	0%	

Table 3.–Estimated length composition of the 2012 sockeye salmon escapement at Kanalku Lake.

Brood year	2008	2007	2007	2006	
Age	1.2	1.3	2.2	3.2	Total
Male					
Sample size	103	13	1	0	117
Mean length (mm)	513	560	530		
SE	4.8	4.2			
Female					
Sample size	179	5	14	2	200
Mean length (mm)	501	552	496	505	
SE	5.0	4.4	5.2	2.7	
All fish					
Sample size	282	19	15	2	318
Mean length (mm)	505	557	498	505	
SE	5.0	4.2	5.3	2.7	

DISCUSSION

The dual camera-weirs located in lower Kanalku Creek, downstream of Kanalku Falls, were used successfully in 2012, and our count of 2,289 sockeye salmon represents the first accurate estimate of the *total* escapement into the Kanalku system. We chose the picket weir count of 1,123 adult sockeye salmon at Kanalku Lake as the best estimate of the *spawning* escapement in 2012, since it fell within the 95% CI of the mark-recapture estimate. A comparison of the camera-weir count from lower Kanalku Creek (2,289) and the picket weir count (1,123) at Kanalku Lake suggests that about 49% of the *total* sockeye salmon escapement successfully ascended Kanalku Falls. Although the fate of the sockeye salmon that did not make it to Kanalku Lake is not entirely certain, we assume they were unable to ascend Kanalku Falls and/or fell prey to predators. The 2012 *spawning* escapement estimate was near the 2001–2011 average of 1,252 sockeye salmon (Appendix A). We did not expect a very large escapement or age diversity of sockeye salmon at Kanalku Lake in 2012 due to the small parent-year spawning escapement of 461 sockeye salmon in 2007 (Figure 11; Appendix A).

It has been suggested that low water flow at Kanalku Falls may favor sockeye salmon passage (Vinzant et al. 2010; Vinzant and Bednarski 2010; Vinzant et al. 2011; Vinzant et al. 2012). Although the water level remained relatively low throughout the sockeye salmon migration in 2012, the observed water level at the picket weir was marginally higher than the 2007–2011 average for most of the season (Figure 12).

ADF&G and the USDA Forest Service have been working cooperatively to improve fish passage and increase sockeye salmon production from the drainage (Bednarski et al. 2013). The Alaska State Legislature allocated $200,000 in capital funds to begin work on further barrier modification of the falls. A National Environmental Protection Act review of the drainage has been completed, and a Finding of No Significant Action was signed by the USFS Supervisor in February 2012. Barrier modification was planned to take place in spring 2013. ADF&G, in cooperation with the USFS and the Angoon Community Association, will continue monitoring the *total* sockeye salmon escapement below Kanalku Falls and the *spawning* escapement at Kanalku Lake in 2013.

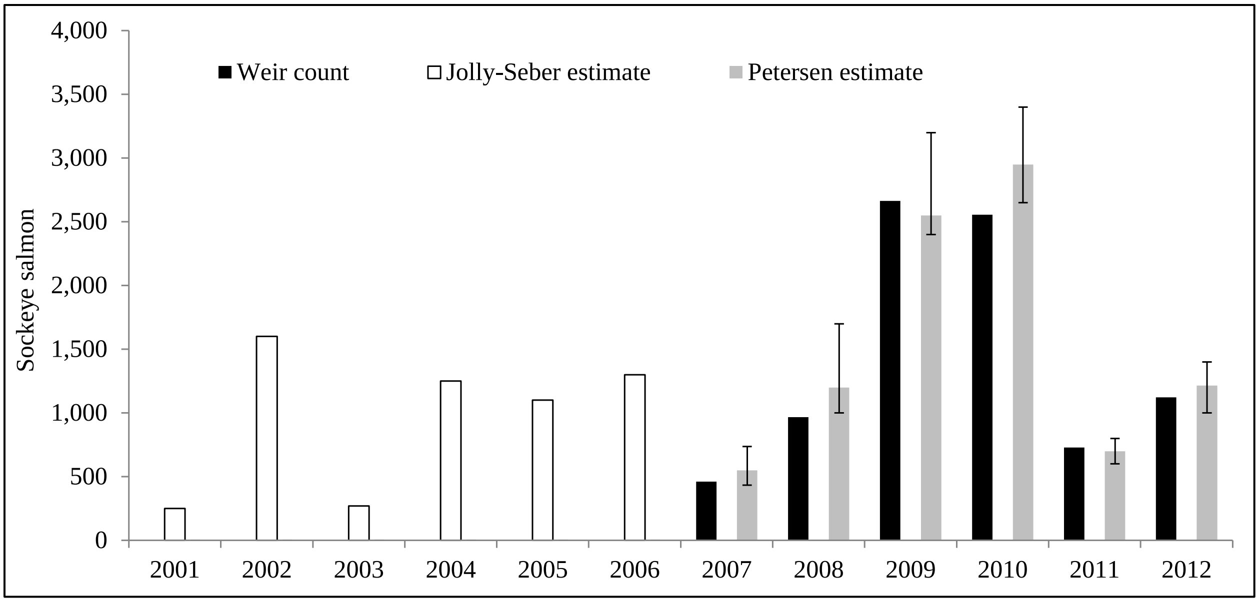

Figure 11.–Estimated adult sockeye salmon escapements at Kanalku Lake from 2001 to 2012. Error bars represent the 95% confidence intervals of the Petersen mark-recapture estimates.

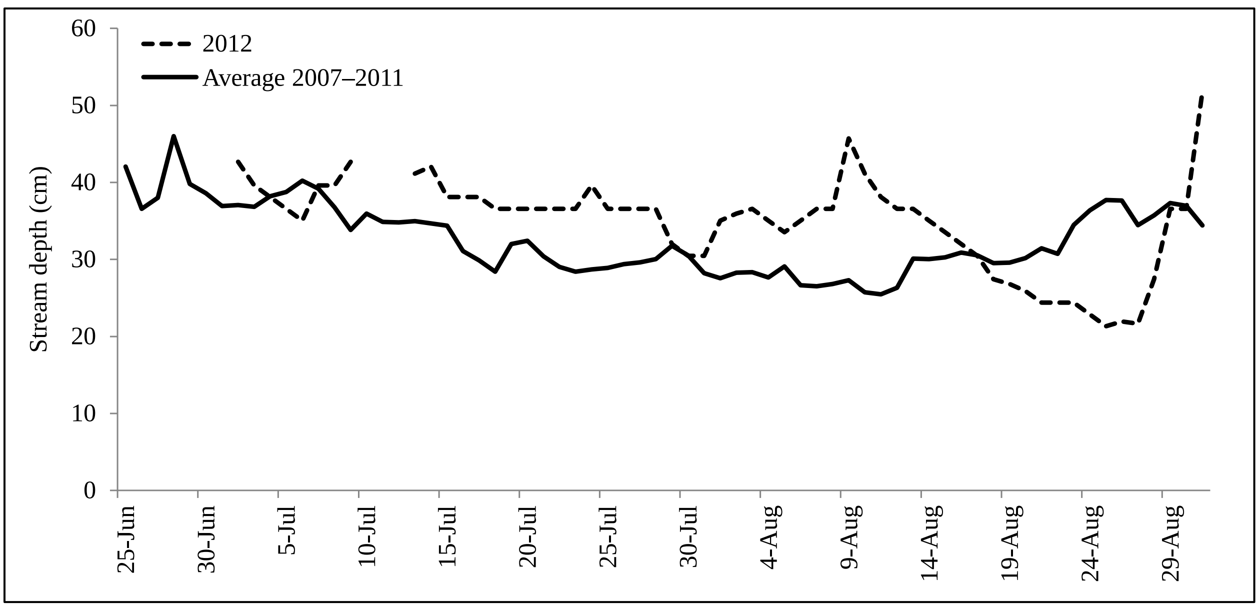

Figure 12.–Stream depth (cm) at the picket weir in 2012 compared to average stream depth (2007–2011).

The sockeye salmon spawning escapement was composed primarily of age-1.2 fish (88%). Although annual escapements are typically composed largely of age-1.2 fish at Kanalku Lake (average 78%; Table 4), the very low number of age-1.3 sockeye salmon found in the 2012 escapement (75 fish) was likely a product of the very small parent-year escapement observed in 2007 (461 fish). Kanalku Lake sockeye salmon runs are among the youngest in age at return and the smallest in size at age in Southeast Alaska. We examined the age and size composition of sockeye salmon at 22 lakes around the region, 2001–2011 (data from ADF&G Southeast Alaska Integrated Fisheries Database; Appendices F and G). Of the 22 systems, Kanalku Lake sockeye salmon escapements had the highest average proportion of age-1.2 fish (78%) and the lowest average proportion of age-1.3 fish (23%; Appendix G). Other lakes in the vicinity also support runs of sockeye salmon with a high proportion of age-1.2 fish, namely Sitkoh and Kook lakes (Appendix G). Additionally, sockeye salmon returning to Kanalku Lake were among the smallest in the region. On average, Kanalku Lake sockeye salmon escapements had the smallest age-1.2, age-2.2, and age-2.3 females, and the smallest age-1.3 and age-2.3 males (Appendix H).

Table 4.–Proportions of aged sockeye salmon sampled at Kanalku Lake from 2001 to 2012.

	Age class						
Year	1.1	1.2	1.3	2.1	2.2	2.3	3.2
2001	0.00	0.55	0.43	0.00	0.02	0.00	0.00
2002	0.00	0.80	0.16	0.00	0.03	0.00	0.00
2003	0.00	0.87	0.11	0.00	0.01	0.00	0.00
2004	0.00	0.76	0.23	0.00	0.01	0.00	0.00
2005	0.00	0.85	0.11	0.01	0.03	0.00	0.00
2006	0.00	0.97	0.03	0.00	0.00	0.00	0.00
2007	0.00	0.37	0.54	0.00	0.08	0.01	0.00
2008	0.00	0.96	0.02	0.00	0.03	0.00	0.00
2009	0.00	0.57	0.37	0.00	0.06	0.00	0.00
2010	0.00	0.87	0.12	0.00	0.01	0.00	0.00
2011	0.00	0.52	0.43	0.00	0.04	0.00	0.00
2012	0.00	0.89	0.06	0.00	0.05	0.00	0.01
Mean	0.00	0.78	0.19	0.00	0.03	0.00	0.00
SE	0.01	0.12	0.11	0.01	0.04	0.01	0.01

CAMERA OPERATIONS

The dual camera-weir video systems worked well throughout the field season and no complete failures of either weir were encountered. Although the upper of the two camera-weirs captured about 1% less sockeye salmon in its video files, the counts were remarkably close and the discrepancy was likely due to predation between the weirs by river otters and brown bears (Figure 13). Structurally, the camera-weirs held up well. We encountered no breaches of the weir or problems with scouring. Damage to the lower camera-weir occurred on two occasions when a brown bear collided with the weir while chasing fish, however, the weir was not compromised and was promptly fixed.

The most notable technical problems associated with the camera-weir operations in 2012 were glare on the water that triggered the motion-activated DVRs and low water conditions that resulted in the right-side cameras, which were positioned at a higher viewing angle, to become un-submerged, making the camera inoperable. Although the DVR systems generally produced clear fish images (Figure 14), the dimensions of the video chutes often precluded a full view of salmon as they passed through, making species identification difficult. The video chutes will be redesigned for the 2013 field season to alleviate these problems.

The mini-DVR recorders worked well enough for capturing fish traveling through the video chutes in lower Kanalku Creek, although some difficulties with their operation were encountered. Obtaining compatible SD cards that would work in the recorders proved difficult, and although the manufacturer claimed that SDHC (secure data high capacity) cards up to 16 GB should work in the mini-DVRs, we had no luck with any memory cards in excess of 2 GB even after installing after-market firmware. However, the count was never compromised since the crew swapped cards daily and the DVR's rarely ran low on memory. The motion-detection capabilities of the mini-DVR units was sufficient for enumerating sockeye salmon, but the lack of a pre-record feature resulted in the DVRs capturing only the tails of many fish that swam through the chutes quickly. This would likely be a much larger problem in other systems with more salmon species diversity as identification would be difficult. Several unexplained failures of the mini-DVRs were also experienced in 2012, but were remedied by switching the power off and back on. It was unclear why they malfunctioned, but fish counts were never compromised.

The solar power system used to supply the camera-weirs worked well throughout the season and no failures were encountered. Two 140W solar panels per camera-weir provided sufficient power, even during prolonged periods of low clouds and poor weather. One 100Ah battery was adequate for each camera-weir. The LED light-strips worked well during the night to illuminate the video chutes and did not exhaust the battery banks. Fish did not appear to shy away from the lights. The dusk-to-dawn photoelectric switches controlling the lighting systems worked adequately, however we did experience flickering during late evenings and early mornings which triggered the DVRs to record. Although inconvenient during review of the video files, this posed no real problem to the video systems other than using up memory space. Repositioning the photoelectric switches away from flickering light may alleviate this in future seasons. A bear fence erected to protect the batteries, DVRs, and associated equipment worked well.

Figure 13.–River otter (top) preying on an adult sockeye salmon (bottom), Kanalku Creek, 2012. The otter swam through the video chute with the sockeye salmon's head in its mouth. (©2012 ADF&G)

Figure 14.–Sockeye salmon captured by video camera, Kanalku Lake, 2012. (©2012 ADF&G)

REFERENCES CITED

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2106.

Bednarski, J., D. K. Harris, K. Monagle, S. C. Heinl, and M. S. Kelley. 2013. Northern Chatham Strait sockeye salmon: Updated stock status, fishery management, and subsistence fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 1J12-14, Douglas.

Betts, M. F., and R. J. Wolfe. 1992. Commercialization of fisheries and the subsistence economies of the Alaska Tlingit. Society and Natural Resources 5:277-295.

Clutter, R., and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin of the International Pacific Salmon Fisheries Commission 9, New Westminster, Canada.

Cochran, W. G. 1977. Sampling techniques, 3rd edition. John Wiley and Sons, New York.

Conitz, J. M., and S. E. Burril. 2008. Kanalku and Sitkoh Lakes subsistence sockeye salmon project: 2006 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 08-29, Anchorage.

Conitz, J. M., and M. A. Cartwright. 2003. Falls, Gut Bay, and Kutlaku Lakes subsistence sockeye salmon project: 2002 Annual Report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J03-42, Juneau.

Conitz, J. M., and M. A. Cartwright. 2005. Kanalku, Sitkoh, and Kook Lakes subsistence sockeye salmon project: 2003 annual report and 2001–2003 final report. Alaska Department of Fish and Game, Fisheries Data Series No. 05-57, Anchorage.

Conover, W. J. 1999. Practical nonparametric statistics, 3rd edition. John Wiley and Sons, Inc., New York.

de Laguna, F. 1960. The story of a Tlingit community: A problem in the relationship between archeological, ethnological, and historical methods. Native American Book Publishers, Brighton, Michigan. U.S. Government Printing Office, Washington, D.C.

Geiger, H., and ADF&G Staff. 2007. Northern Chatham Strait sockeye salmon: stock status, fishery management, and subsistence fisheries. Alaska Department of Fish and Game, Special Publication No. 7-15, Anchorage.

Goldschmidt, W. R., and T. R. Haas. 1998. Haa Aaní, Our Land: Tlingit and Haida land rights and use. University of Washington Press, Seattle and London. Sealaska Heritage Foundation, Juneau.

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report 1961. Vancouver, Canada.

Koo, T. S. Y. 1962. Age designation in salmon. [*In*] Studies of Alaska red salmon. University of Washington Press, Seattle.

Lewis, B. A., and M. A. Cartwright. 2004. Hetta Lake sockeye salmon stock assessment project: 2002 annual report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J04-10, Juneau.

Lorrigan, J., M. Cartwright, and J. Conitz. 2004. Klag Bay sockeye stock assessment, 2002. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J04-18, Juneau.

Moss, M. L. 1989. Archaeology and cultural ecology of the prehistoric Angoon Tlingit. PhD Dissertation, University of California, Santa Barbara.

Nowacki, G., P. Krosse, G. Fisher, D. Brew, T. Brock, M. Shephard, W. Pawuk, J. Baichtal, and E. Kissinger. 2001. Ecological subsections of Southeast Alaska and neighboring areas of Canada. U.S. Department of Agriculture, Forest Service, Alaska Region, Technical Publication No. R10-TP-75.

Schwarz, C. J., and C. G. Taylor. 1998. Use of the stratified-Petersen estimator in fisheries management: estimating the number of pink salmon (*Oncorhynchus gorbuscha*) spawners in the Fraser River. Canadian Journal of Fisheries and Aquatic Sciences 55:281–296.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, 2nd ed. Charles Griffin and Sons, Ltd., London.

References Cited (continued)

Thompson, S. K. 1992. Sampling. Wiley-Interscience, New York.

Thornton, T. F., R. F. Schroeder, and R. G. Bosworth. 1990. Use of sockeye salmon at Sitkoh Bay, Alaska. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper No. 174, Douglas.

Turek, M. F., A. Paige, E. Cheney, J. Dizard, and N. Soboleff. 2006. Kake subsistence harvest use pattern. Alaska Department of Fish and Game, Division of Subsistence, Technical Report No. 309, Juneau.

Vinzant, R. F., and J. Bednarski. 2010. Kanalku Lake subsistence sockeye salmon project: 2009 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 10-67, Anchorage.

Vinzant. R. F., J. Bednarski, and S. C. Heinl. 2012. Kanalku Lake subsistence sockeye salmon project: 2011 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 12-76, Anchorage.

Vinzant, R. F., S. A. Host, and J. M. Conitz. 2009. Kanalku Lake subsistence sockeye project: 2007 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 09-71, Anchorage.

Vinzant, R. F., J. M. Conitz, and M. A. Blikshteyn. 2010. Kanalku Lake subsistence sockeye project: 2008 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 10-13, Anchorage.

Vinzant, R. F., J. Bednarski, and S. C. Heinl. 2011. Kanalku Lake subsistence sockeye salmon project: 2010 annual report. Alaska Department of Fish and Game, Fishery Data Series No. 11-40, Anchorage.

Walker, R. 2009. The validity and reliability of fisheries harvest monitoring methods, Southeast Alaska. Alaska Department of Fish and Game, Division of Subsistence, Technical Paper No. 286, Anchorage.

APPENDICES

Appendix A.–Kanalku Lake annual estimated sockeye salmon *spawning* escapement and subsistence harvest 2001–2012. Escapement estimates were based on weir and mark-recapture estimates, and the annual estimate used as the final estimate is shown in bold. Subsistence harvest was reported from returned ADF&G subsistence salmon fishing permits. There was a voluntary subsistence closure from 2002 to 2005.

		Mark-recapture estimate					
Year	Weir count	Petersen estimate	Jolly-Seber estimate	95% CI	Expanded Jolly-Seber[a]	Final escapement estimate	Subsistence harvest
2001	–	–	250	130–380	250	250	951
2002	–	–	1,300	1,200–1,400	1,600	1,600	14
2003	–	–	280	250–300	280	280	90
2004	–	–	820	750–900	1,250	1,250	60
2005	–	–	950	900–1,000	1,100	1,100	50
2006	–	–	1,100	1,000–1,200	1,300	1,300	51
2007	461	576	–	430–-740	–	461	10
2008	967	1,200	–	1,000–1,500	–	1,200	708
2009	2,664	2,750	–	2,500–3,200	–	2,664	600
2010	2,555	2,970	–	2,660–3,380	–	2,970	571
2011	728	690	–	600–800	–	728	419
2012	1,123	1,215	–	1,000–1,400	–	1,123	NA[b]

[a] Jolly-Seber estimates from 2001 to 2006 were expanded based on the ratio of the number sockeye salmon observed in the mark-recapture study area to the number observed in the entire lake (Conitz and Burril 2008).

[b] Subsistence harvest data for 2012 were not available at the time of publication.

Appendix B.–Detection of size and/or sex selective sampling during a two-sample mark recapture experiment and its effects on estimation of population size and population composition

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (chi2 test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M and R, C and R, and M and C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g., Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:

Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:

Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:

Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:

Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test will likely detect small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R *P*-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R *P*-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

-continued-

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R *P*-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R *P*-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{ ; and,} \tag{1}$$

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left(\sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + \left(\hat{p}_{ik} - \hat{p}_k \right)^2 \hat{V}[\hat{N}_i] \right). \tag{2}$$

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size *k* among fish in stratum *i*;

$\hat{N}_i$ = the estimated abundance in stratum *i*; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

-continued-

Results of the Kolmogorov-Smirnov test statistics for analysis of size-selective sampling of sockeye salmon at Kanalku Lake, 2012, suggest a *Case II* situation.

Event evaluation	Hypothesis test	Sample size (*n*)	D Statistic	*P* Value	Result
Event 1	There is no size difference between all fish captured (*c*) in Event 2, and marked fish recaptured (*r*) in Event 2.	*c*(227) *r*(83)	0.04	0.99	Not rejected
Event 2	There is no size difference between fish marked (*m*) in Event 1, and marked fish recaptured (*r*) in Event 2.	*m*(360) *r*(83)	0.31	<0.01	Rejected

The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week were calculated using equations from Cochran (1977).

Let

h = index of the stratum (week),

j = index of the age class,

p_{hj} = proportion of the sample taken during stratum h that is age j,

n_h = number of fish sampled in week h, and

n_{hj} = number observed in class j, week h.

Then the age distribution was estimated for each week of the escapement in the usual manner:

$$\hat{p}_{hj} = n_{hj} / n_h \ . \qquad (1)$$

If N_h equals the number of fish in the escapement in week h, standard errors of the weekly age class proportions are calculated in the usual manner (Cochran 1977, page 52):

$$SE(\hat{p}_{hj}) = \sqrt{\left[\frac{(\hat{p}_{hj})(1-\hat{p}_{hj})}{n_h - 1}\right][1 - n_h / N_h]} \, . \qquad (2)$$

The age distributions for the total escapement were estimated as a weighted sum (by stratum size) of the weekly proportions. That is,

$$\hat{p}_j = \sum_h p_{hj} (N_h / N), \qquad (3)$$

such that N equals the total escapement. The standard error of a seasonal proportion is the square root of the weighted sum of the weekly variances (Cochran 1977, pages 107–108):

$$SE(\hat{p}_j) = \sqrt{\sum_j^h [SE(\hat{p}_{hj})]^2 (N_h / N)^2} \ . \qquad (4)$$

The mean length, by sex and age class (weighted by week of escapement), and the variance of the weighted mean length, were calculated using the following equations from Cochran (1977, pages 142–144) for estimating means over subpopulations. That is, let i equal the index of the individual fish in the age-sex class j, and y_{hij} equal the length of the ith fish in class j, week h, so that,

$$\hat{\bar{Y}}_j = \frac{\sum_h (N_h / n_h) \sum_i y_{hij}}{\sum_h (N_h / n_h) n_{hj}} \text{, and} \qquad (5)$$

$$\hat{V}\left(\hat{\bar{Y}}_j\right) = \frac{1}{\hat{N}_j^2} \sum_h \frac{N_h^2 (1 - n_h / N_h)}{n_h (n_h - 1)} \left[\sum_i (y_{hij} - \bar{y}_{hj})^2 + n_{hj} \left(1 - \frac{n_{hj}}{n_h}\right) \left(\bar{y}_{hj} - \hat{\bar{Y}}_j\right)^2 \right].$$

Appendix D.–Number of sockeye, pink, coho, Chinook, and chum salmon counted in the lower video-camera weir in Kanalku Creek, 2012.

Date	Sockeye salmon	Pink salmon	Coho salmon	Chinook salmon	Chum salmon
13-Jun	0	0	0	0	0
14-Jun	0	0	0	0	0
15-Jun	0	0	0	0	0
16-Jun	0	0	0	0	0
17-Jun	0	0	0	0	0
18-Jun	0	0	0	0	0
19-Jun	0	0	0	0	0
20-Jun	0	0	0	0	0
21-Jun	0	0	0	0	0
22-Jun	0	0	0	0	0
23-Jun	0	0	0	0	0
24-Jun	1	0	0	0	0
25-Jun	4	0	0	0	0
26-Jun	0	0	0	0	0
27-Jun	0	0	0	0	0
28-Jun	0	0	0	0	0
29-Jun	1	0	0	0	0
30-Jun	0	0	0	0	0
1-Jul	0	0	0	0	0
2-Jul	0	0	0	0	0
3-Jul	6	0	0	0	0
4-Jul	0	0	0	0	0
5-Jul	2	0	0	0	0
6-Jul	7	0	0	0	0
7-Jul	13	0	0	0	0
8-Jul	25	0	0	0	0
9-Jul	5	0	0	0	0
10-Jul	36	0	0	0	0
11-Jul	19	0	0	0	0
12-Jul	12	0	0	0	0
13-Jul	1	0	0	0	0
14-Jul	7	0	0	0	0
15-Jul	9	0	0	0	0
16-Jul	47	0	0	0	0
17-Jul	20	0	0	0	0
18-Jul	22	0	0	0	0
19-Jul	76	0	0	0	0
20-Jul	157	0	0	0	0
21-Jul	53	0	0	0	0
22-Jul	33	0	0	0	0
23-Jul	249	0	0	0	0
24-Jul	13	0	0	0	0
25-Jul	64	0	0	0	0
26-Jul	27	0	0	0	0
27-Jul	46	0	0	0	0
28-Jul	270	0	0	0	0

-continued-

Appendix D.–Page 2 of 2.

Date	Sockeye salmon	Pink salmon	Coho salmon	Chinook salmon	Chum salmon
29-Jul	18	0	0	0	0
30-Jul	79	0	0	0	0
31-Jul	256	0	0	0	0
1-Aug	163	1	0	0	0
2-Aug	48	0	0	0	0
3-Aug	31	0	0	0	0
4-Aug	45	0	0	0	0
5-Aug	53	0	0	0	0
6-Aug	31	0	0	0	0
7-Aug	35	0	0	0	0
8-Aug	7	0	0	1	0
9-Aug	90	1	0	0	0
10-Aug	44	5	0	0	0
11-Aug	23	5	0	0	0
12-Aug	7	3	0	0	0
13-Aug	14	0	0	0	0
14-Aug	17	6	0	0	0
15-Aug	11	6	0	0	0
16-Aug	22	7	0	1	0
17-Aug	25	27	1	0	0
18-Aug	5	36	0	0	0
19-Aug	8	36	0	0	0
20-Aug	1	21	0	0	2
21-Aug	6	15	0	0	0
22-Aug	6	25	0	0	0
23-Aug	4	57	1	0	3
24-Aug	4	53	0	0	0
25-Aug	5	11	0	0	2
26-Aug	5	27	0	0	1
27-Aug	1	44	0	0	3
28-Aug	0	24	0	0	0
Total	2,289	410	2	2	11

Appendix E.–Picket weir daily and cumulative counts of sockeye salmon, water depth, and temperature at Kanalku Lake in 2012. No other salmon species were observed.

	Sockeye salmon			Water	Air
Date	Daily	Cumulative	Water depth (cm)	temperature (^oC)	temperature (^oC)
25–Jun	0	0	ND	ND	ND
26–Jun	0	0	ND	ND	ND
27–Jun	0	0	ND	ND	ND
28–Jun	0	0	ND	ND	ND
29–Jun	0	0	ND	ND	ND
30–Jun	0	0	ND	ND	ND
1–Jul	0	0	ND	ND	ND
2–Jul	0	0	43	11.0	14.0
3–Jul	0	0	40	10.0	16.0
4–Jul	0	0	38	11.0	12.5
5–Jul	0	0	37	11.0	12.5
6–Jul	0	0	35	11.5	14.0
7–Jul	0	0	40	11.0	11.0
8–Jul	0	0	40	11.5	12.5
9–Jul	0	0	43	11.0	11.5
10–Jul	0	0	ND	11.5	11.0
11–Jul	0	0	ND	10.0	14.0
12–Jul	0	0	ND	11.0	15.0
13–Jul	0	0	41	11.0	12.5
14–Jul	0	0	42	11.0	12.0
15–Jul	2	2	38	11.5	13.5
16–Jul	0	2	38	11.5	13.5
17–Jul	0	2	38	11.5	13.0
18–Jul	0	2	37	12.0	13.0
19–Jul	5	7	37	12.5	12.0
20–Jul	2	9	37	13.0	14.0
21–Jul	5	14	37	14.0	15.0
22–Jul	28	42	37	14.0	16.0
23–Jul	21	63	37	14.0	14.0
24–Jul	46	109	40	13.0	14.0
25–Jul	25	134	37	13.0	14.0
26–Jul	44	178	37	13.0	15.0
27–Jul	108	286	37	16.0	14.0
28–Jul	40	326	37	14.0	16.0
29–Jul	83	409	32	15.0	14.0
30–Jul	54	463	30	15.0	15.0
31–Jul	84	547	30	14.5	11.5
1–Aug	42	589	35	14.0	13.5
2–Aug	54	643	36	13.5	12.5

-continued-

Date	Sockeye salmon Daily	Sockeye salmon Cumulative	Water depth (cm)	Water temperature (^{o}C)	Air temperature (^{o}C)
3–Aug	37	680	37	12.5	4.50
4–Aug	23	703	35	13.5	4.45
5–Aug	21	724	34	13.5	4.40
6–Aug	48	772	35	13.5	4.45
7–Aug	24	796	37	15.0	4.50
8–Aug	45	841	37	15.0	4.50
9–Aug	39	880	46	12.0	4.80
10–Aug	14	894	41	14.0	4.65
11–Aug	3	897	38	14.0	4.55
12–Aug	15	912	37	14.0	4.50
13–Aug	10	922	37	13.5	4.50
14–Aug	14	936	35	14.5	4.45
15–Aug	7	943	34	13.5	4.40
16–Aug	6	949	32	14.0	4.35
17–Aug	6	955	30	13.5	4.30
18–Aug	23	978	27	14.0	4.20
19–Aug	11	989	27	16.0	4.18
20–Aug	34	1023	26	13.5	4.15
21–Aug	15	1038	24	13.5	4.10
22–Aug	8	1046	24	13.5	4.10
23–Aug	23	1069	24	12.0	4.10
24–Aug	12	1081	23	13.0	4.05
25–Aug	12	1093	21	14.0	4.00
26–Aug	7	1100	22	12.0	4.02
27–Aug	3	1103	22	13.5	4.01
28–Aug	9	1112	27	12.5	4.20
29–Aug	6	1118	37	14.0	4.50
30-Aug	0	1118	37	14.0	4.50
31-Aug	0	1118	52	13.0	5.00
1-Sep	2	1120	37	11.5	4.50
2-Sep	0	1120	34	12.0	4.40
3-Sep	0	1120	30	13.0	4.30
4-Sep	3	1123	27	ND	4.20

Appendix F.–Sample size of sockeye salmon marked at the weir (*m*), all fish sampled on the spawning grounds (*c*), and marked fish recovered on the spawning grounds (*r*), by sex, at Kanalku Lake in 2012.

Sex	Group	Number sampled
Female	Marked in Event 1 (*m*)	226
Female	All fish sampled in Event 2 (*c*)	102
Female	Marked fish recovered in Event 2 (*r*)	36
Male	Marked in Event 1 (*m*)	133
Male	All fish sampled in Event 2 (*c*)	105
Male	Marked fish recovered in Event 2 (*r*)	38

Appendix G.–Average age composition of 22 Southeast Alaska sockeye salmon escapements, 2001–2011. Data from ADF&G Southeast Alaska Integrated Fisheries Database.

	Age class						
System	1.1	2.1	1.2	2.2	1.3	2.3	Other
Kanalku Lake	0%	0%	73%	3%	23%	0%	0%
Kook Lake	1%	0%	58%	3%	38%	0%	0%
Speel Lake	3%	0%	49%	1%	46%	0%	1%
Neva Lake	9%	2%	47%	9%	31%	2%	0%
Sitkoh Lake	1%	0%	45%	1%	52%	0%	0%
Hetta Lake	3%	0%	45%	2%	48%	2%	0%
Kegan Lake	4%	1%	44%	6%	44%	2%	0%
Ford Arm Lake	11%	3%	39%	9%	30%	7%	0%
Red Bay Lake	19%	4%	34%	3%	39%	2%	0%
Petersburg Creek	12%	6%	32%	11%	30%	9%	0%
Klawock Lake	5%	2%	31%	18%	37%	6%	0%
Hugh Smith Lake	1%	0%	30%	12%	46%	10%	1%
Salmon Bay Lake	2%	3%	28%	5%	54%	5%	2%
Karta Lake	2%	0%	28%	3%	63%	4%	0%
Klag Lake	2%	2%	25%	18%	41%	11%	0%
Falls Lake	0%	0%	25%	22%	35%	17%	0%
Redoubt Lake	2%	3%	24%	20%	40%	11%	0%
Klakas Lake	1%	0%	22%	6%	58%	13%	0%
Kah Sheets Creek	0%	0%	21%	23%	42%	14%	0%
McDonald Lake	1%	1%	16%	6%	59%	17%	0%
Chilkoot Lake	0%	0%	15%	2%	74%	8%	1%
Chilkat Lake	0%	1%	5%	18%	38%	36%	2%
Kanalku Rank	21	17	1	18	22	22	

Appendix H.–Average mideye to fork length (mm) composition of 22 Southeast Alaska sockeye salmon escapements, by age and sex, 2001–2011. Data from ADF&G Southeast Alaska Integrated Fisheries Database.

	Male				Female			
System	Age-1.2	Age-1.3	Age-2.2	Age-2.3	Age-1.2	Age-1.3	Age-2.2	Age-2.3
Chilkat Lake	508	596	536	598	529	581	529	582
Chilkoot Lake	485	580	496	579	506	567	510	564
Falls Lake	502	557	506	556	497	551	509	551
Ford Arm Lake	503	569	509	569	498	541	499	541
Hetta Lake	505	566	501	560	496	548	506	545
Hugh Smith Lake	525	595	533	597	525	581	530	581
Kah Sheets Creek	518	574	526	574	518	574	526	574
Kanalku Lake	494	551	516	538	485	539	489	540
Karta Lake	524	592	524	586	519	566	524	566
Kegan Lake	509	571	516	575	507	565	567	539
Klag Lake	493	554	499	551	488	544	491	542
Klakas Lake	519	579	529	587	503	554	516	565
Klawock Lake	516	576	521	576	507	554	513	551
Kook Lake	499	557	515	575	490	538	506	541
McDonald Lake	509	589	516	581	518	568	518	566
Neva Lake	517	575	534	577	511	560	513	551
Petersburg Creek	449	574	455	580	505	561	507	564
Red Bay Lake	470	577	477	575	503	556	536	555
Redoubt Lake	512	572	514	572	501	546	497	542
Salmon Bay Lake	498	584	503	578	502	556	520	552
Sitkoh Lake	495	552	505	561	489	537	491	545
Speel Lake	462	580	477	597	500	569	495	568
Average	502	573	511	574	505	557	514	555
Kanalku Rank	17	22	10	22	22	20	22	21